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für Bildung
und Forschung

Statistical modeling of fire brigade operations w.r.t. extreme precipitation events over Berlin

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Foto: Spreepicture

Extreme precipitation events

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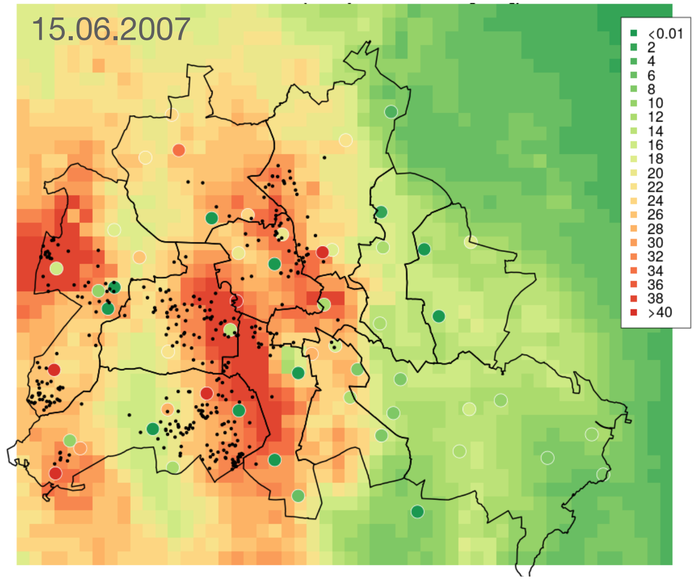
Available Data



- Precipiation:
  - DWD-Radar Climatology[1] (5 min, 1 km)
- Operation data of Berlin fire brigade w.r.t. water damage:
  - Adress specific
  - 2001-2012, 2018-2020

Identify 100 most severe summer (AMJJAS) events.

- Calculate precipitation area mean (radar based) over Berlin.
- Identify event (definition: >0.1 mm of the area mean for more than 2 consecutive time steps).
- Rank according to the num of operations sum per event.

Number	Date and Time (CET)	Prec sum (mm)	Total number of operations
1	07.07.2006 15:00 – 08.07.2006 09:00	23	1202
2	15.06.2007 21:00 – 16.06.2007 10:00	30	533
...	...	...	...
100	24.08.2011 19:00 – 25.08.2011 00:00	15	11

Model operation data individually for every radar cell

- For every time step the number of operations within the next 6h is taken into account.
- Every event within the top 100 is treated equally.

[1] Winterrath, T. et al. (2018): RADKLIM Version 2017.002: Reprocessed quasi gauge-adjusted radar data, 5-minute precipitation sums (YW)

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Statistical model for fire brigade operations

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Apply a (linear) regression…?

Solution: two part hurdle model[2]

- 1st part: addresses occurrence probability of one or more ops.
  —> Logistic Regression
- 2nd part: distribution of operation counts (given that a operation occurs)
  —> Regression w/ distribution with dispersion-parameter

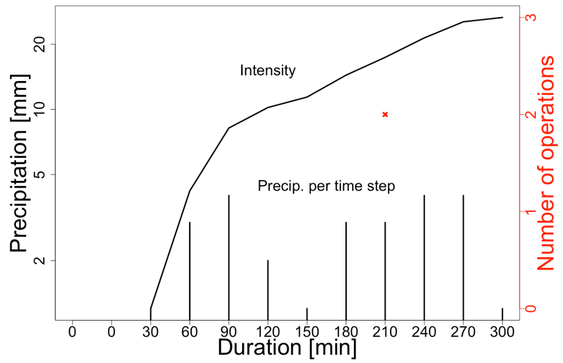
Predictors for the hurdle model parameter:

Occurrence of fire brigade operations

(Number of operations analogously)

~

Prec. amount and duration:



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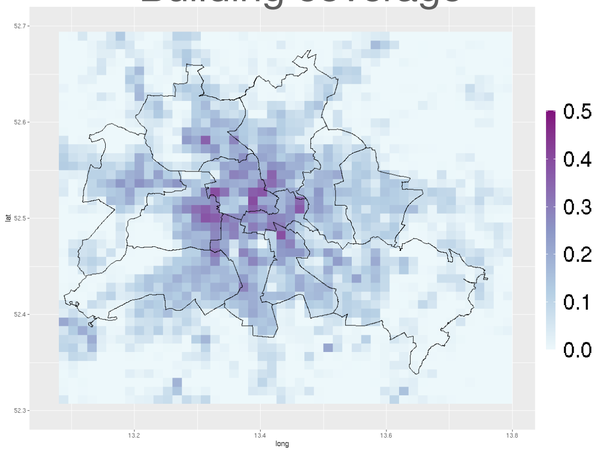
Building coverage



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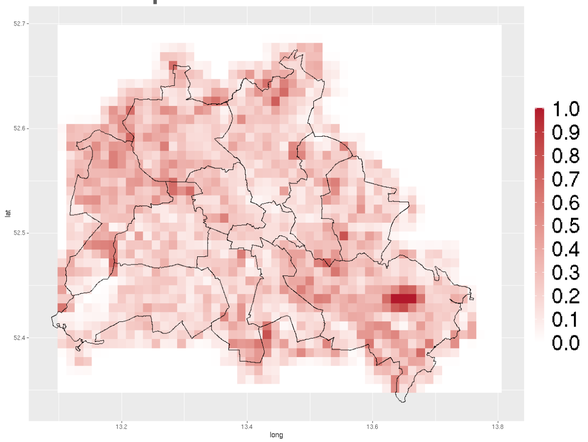
Proportion of sinks



[2]Mullahy, J. (1986): Specification and Testing of some Modified Count Data Models, J. Econometrics, 33, 341–365, https://doi.org/10.1016/0304-4076(86)90002-3.

Model skill

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Predictor impact for all grid cells:

Brier Skill Score (Num of op. > 0)

Reference: Empirical occurrence probability

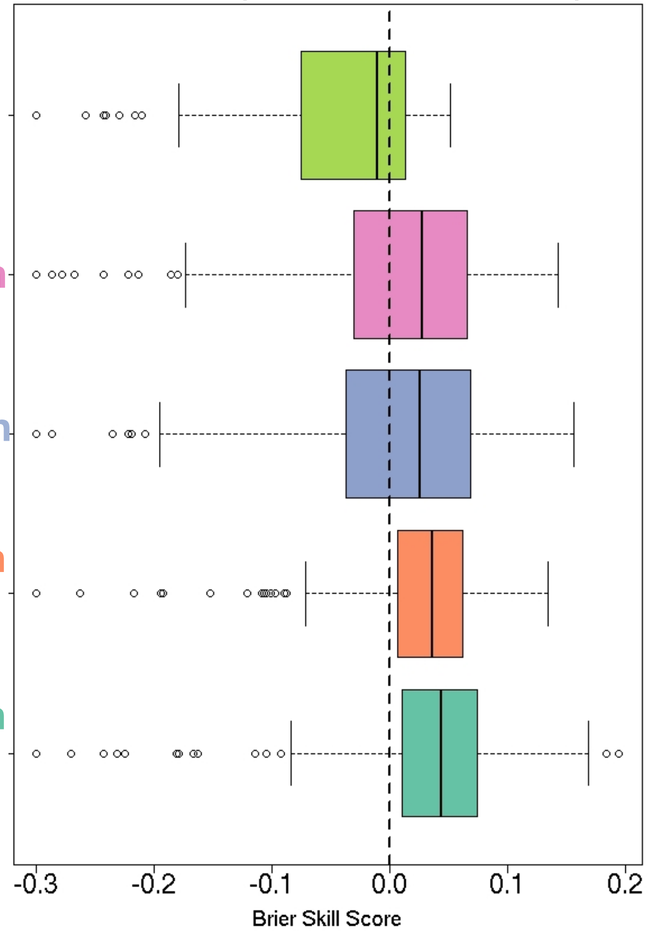
Either prec. amount or duration

Prec. amount and duration no interaction

Prec. amount and duration w/ interaction

Prec. amount and duration w/ interaction and building coverage

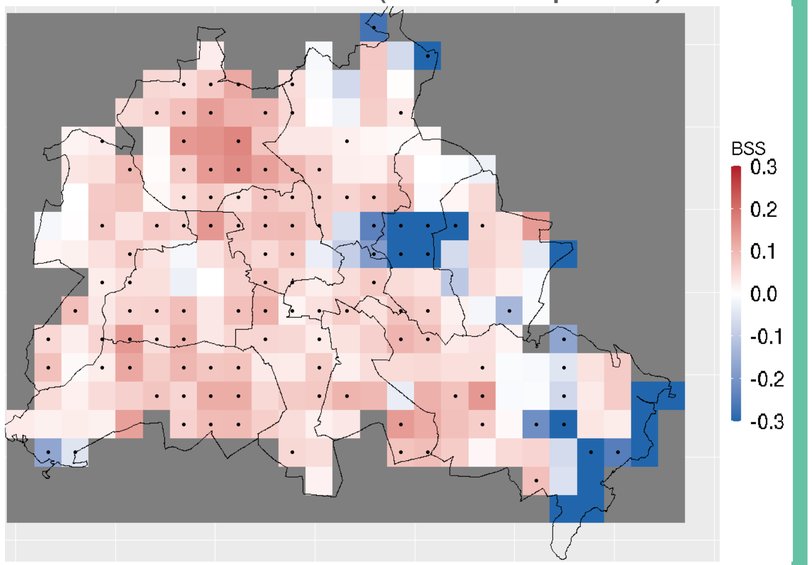
Prec. amount and duration w/ interaction and building coverage and proportion of sinks



(BSS was calculated within 10-fold cross validation setup.)

Skill for the best setup (grid cell-wise)

Brier Skill Score (Num of op. > 0)



Take home:

- Significant skill with combination of:
  - precipitation duration and amount,
  - building and
  - sink density.
- Similar significant BSS values for number of operations > 5 (not shown).

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Appendix

Statistical model

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- For statistical modeling the problem occurs that the number of recorded events is small, and the corresponding poisson-distribution is highly overdispersive.

- Solution: **two part hurdle model** (Mullahy, 1986)

$$f(y \mid \pi, \mu, \theta) = \begin{cases} 1 - \pi & y = 0 \\ \pi \cdot f_{ZTNB}(y \mid \mu, \theta) & y \in \{1,2,...\} \end{cases}$$

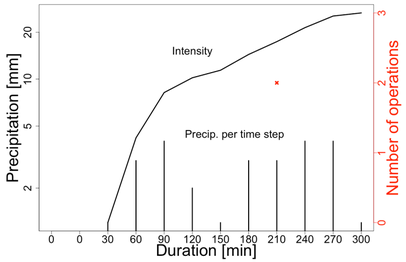
- Binary part: for the occurrence probability π, thus addressing the large amount of zeros in the data (Bernoulli dist.).
- Truncated part: distribution of operation counts (given that a operation occurs) with location parameter π and dispersion parameter θ (zero-truncated negative binomial dist).

Additive model for the corresponding moments:

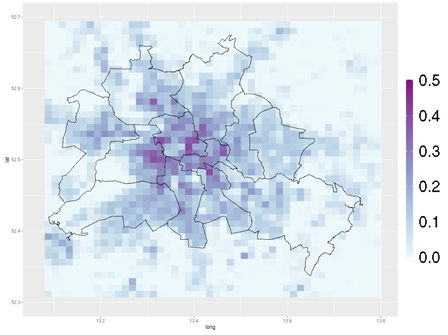
$$log(-log(1-\pi)) = \beta_{0,\pi} + f_{1,\pi}(int, dur) + f_{2,\pi}(sink) + f_{3,\pi}(build)$$
$$log(\mu) = \beta_{0,\mu} + f_{1,\mu}(int, dur) + f_{2,\mu}(sink) + f_{3,\mu}(build)$$
$$log(\theta) = \beta_{0,\theta} + f_{1,\theta}(int, dur) + f_{2,\theta}(sink) + f_{3,\theta}(build)$$

Predictor variables:

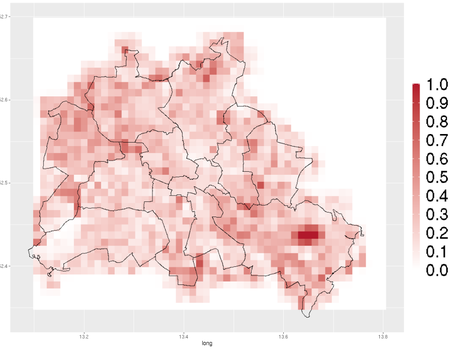
Intensity (int) and duration (dur):



Building density (build):



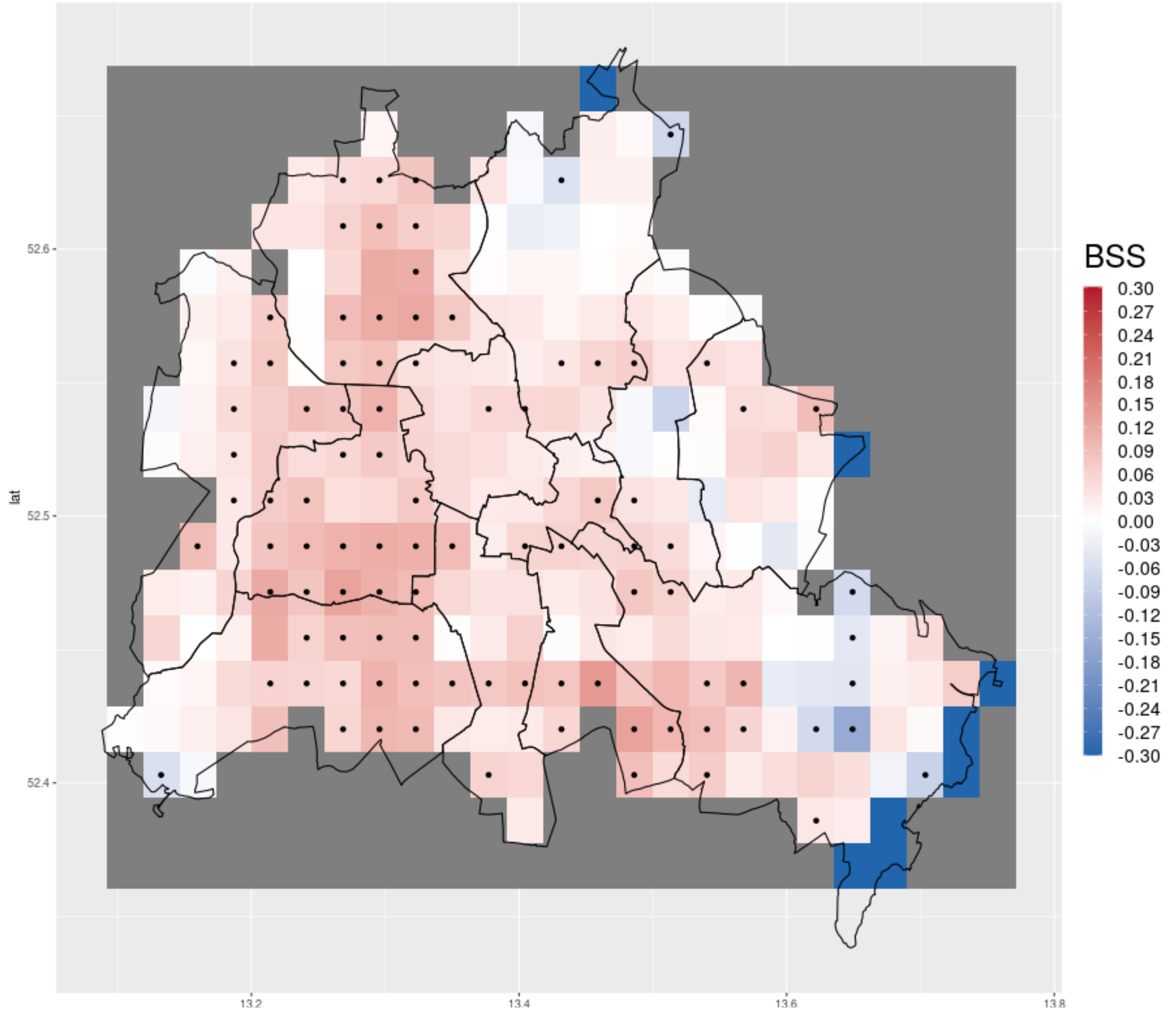
Proportion of sinks (sink):

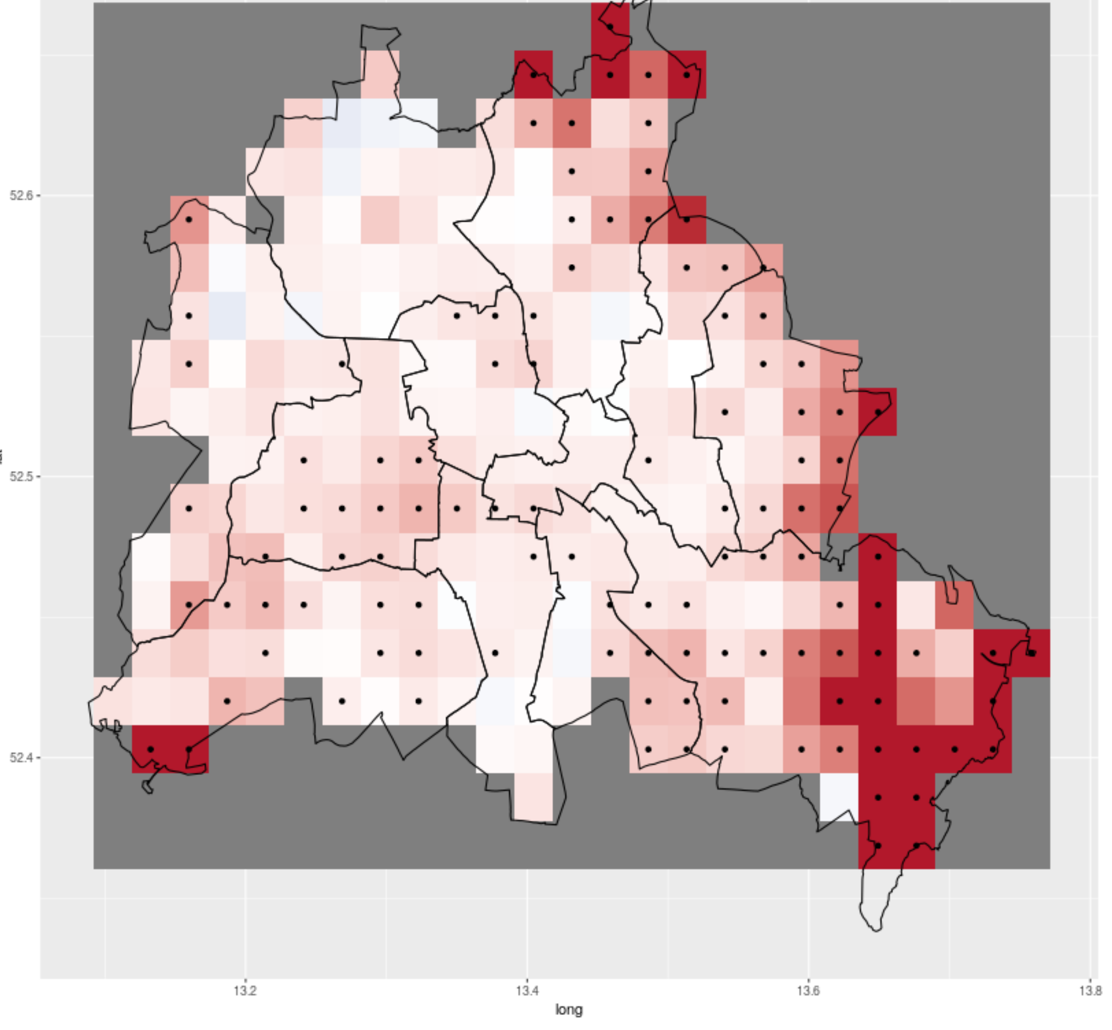


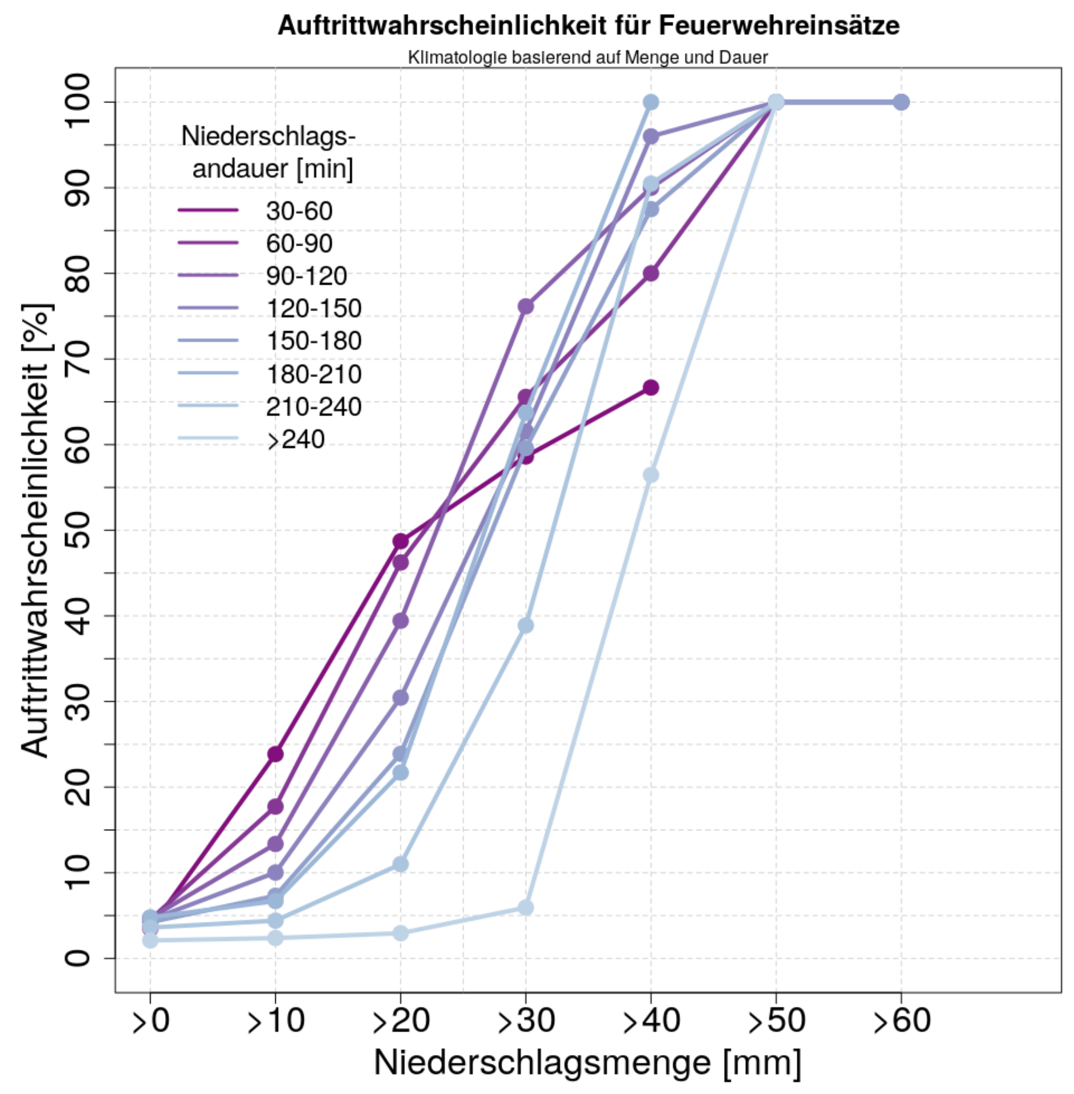
Skill of complete model

Ref: Climatology | Ref: Climatology w.r.t. int and duration

BSS (Num of op > 0)







BSS (Num of op > 5)